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CIVIL ENGINEERING FEATURES OF DELTA STEAM ELECTRIC STATION

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CIVIL ENGINEERING FEATURES
OF
DELTA STEAM ELECTRIC STATION

George E. Archibald,[1] A.M. ASCE

The design of steam-electric power stations is constantly changing. At any given time, however, much of the design may be said to be more or less standardized and contemporary plants differ mainly in size, arrangement and architecture, with occasional features peculiar to the particular location. Delta Steam Electric Station in Mississippi is a good example of today's standardized outdoor type of station and it has a condensing water feature suited to its particular location. Although the preponderance of engineering work required in designing such a plant is mechanical and electrical, the civil engineering considerations involved are important and worth discussion.

Location

The initial development of Delta Steam Electric Station was designed and constructed by Ebasco Services Incorporated for Mississippi Power & Light Company. Its location was decided by the economics of fuel and of electrical transmission. It is situated on Highway U.S. 61, just north of Cleveland, Mississippi, about midway between Vicksburg, Mississippi and Memphis, Tennessee, and more or less in the center of the Delta area. The Mississippi River is about twenty miles distant to the west. The Big Sunflower River flows north to south about a mile and a half east of the plant yard. The station property covers a section and a half of land, the plant occupying a half section adjacent to the highway while the cooling pond occupies a section of land immediately to the east. Railway facilities are provided by spur tracks from the Yazoo and Mississippi Valley Railway which traverses the area. The access road from the highway terminates in a loop which serves the different parts of the plant.

General Design

The essential design features at Delta Station were based on those incorporated in a design that was used jointly by three mid-south companies. The plant arrangement is based on an ultimate installation of four complete units, all controlled from one center. The turbine-generators are arranged in line east to west, all being the same hand in orientation, and two on each side of a north to south plant centerline. The four boilers are in a square formation north of the turbine-generators with two on each side of, and facing inward on, a central area reserved for future coal bunkers. Auxiliary equipment areas are located immediately north of the turbine-generators. These areas are utilized on two levels, one the ground floor and the other a reinforced concrete deck supported on steel framing at the level of the turbine operating deck.

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1. Civil Engineer Ebasco Services Inc., New York.

The initial installation comprises the western half of the ultimate plant arrangement.

The two initial turbine-generators are each of 100 megawatts capacity, designed to operate at 1450 psig and 1000 F at throttle. Each unit has its own boiler, condensers, heat exchangers, pumps and fans, etc., there being no interconnection between units except electrically through the switchyard. Fuel will be natural gas, with oil standby, and with provision for future conversion to pulverized coal if desired when fuel economics dictates.

Each turbine has two side condensers set at grade, one on each side of the turbine pedestal. These condensers are connected to each other and to the turbine bottom exhaust flange by a tee-shaped duct without expansion joints. Expansion and contraction of condensers and duct are accommodated by supporting the condensers on rocker columns. The turbine-generator pedestals have wings cantilevered out on each side at operating deck level to carry the tracks for a 50-ton gantry crane which straddles the line of turbine-generators. A runway extension of steel framing allows the crane to travel beyond the most westerly machine to straddle the end of a railway spur for unloading.

Power is generated at 13.8 kv and is stepped up to 110 kv in a three-phase transformer immediately south of each generator. From there it passes to the ring bus in the 110 kv switchyard still farther south where it is distributed to the feeder transmission lines.

On account of the level nature of the country and its slow drainage, an area sufficient for the plant yard was raised about three feet above the surrounding level by a rolled fill of the native material. The yard is approximately at Elevation 141 and permits good drainage of storm water from the yard by gravity. The plant itself is all above yard grade with first floor level at Elevation 142. The yard paving and earth surfaces are sloped so as to drain to concrete catch-basins, and from these catch-basins the storm water is carried in concrete pipes outside the plant island.

Fully enclosed buildings at Delta Station are limited to a two-story control house with control room at operating deck level; a one-story service building covering approximately 7000 square feet of area which contains the offices, shops, laboratory, lockers and assembly room; a water treatment building, and a standard type sheet-metal warehouse. The control building, service building and water treatment building have steel framing and concrete block walls. Space under equipment operating decks is not enclosed. Corrugated asbestos siding is used to enclose the boiler firing aisles and the space for storage under the boilers, and removable corrugated asbestos barriers protect the boiler feed pump and hydrogen equipment working areas, which are under the operating decks. The turbine-generators have "walk-in" steel enclosures, provided as part of the machine, at both turbine and exciter ends.

A total of approximately 1200 tons of structural steel was used in the framing of the two boilers and 325 tons for other building framing. Approximately 15,000 cubic yards of reinforced concrete were placed for all structures, including foundations, this concrete being furnished from a commercial plant in Cleveland, Mississippi, four and one half miles away. Concrete was, for the most part, a nominal 1:2:4 mix with compressive strength of 3000 psi at 28 days. The usual check by control test cylinders was made for all of this concrete. No admixtures were used.

Pile Foundations

Exploratory soil borings at Delta station site revealed clays down to a depth of 20 to 25 feet, followed by several feet of sandy silt or silty sand. Beyond

this, gray sand is encountered, grading from loose to medium at 30 to 35 feet and beyond this to dense, with some small gravel below 70 feet. The deepest exploratory boring terminated at 100 feet.

The soil at the surface is locally known as "buckshot" because of its property of breaking into small angular particles when it dries out. This clay absorbs large quantities of water rapidly and dries out with equal rapidity, swelling and becoming spongy when wet, and with widespread cracking in the drying process. These characteristics make it an unsatisfactory material on which to place structure foundations, though shear tests made on undisturbed samples taken at depths of about five feet showed that a bearing capacity from 2600 to 4600 pounds per square foot could be obtained with a safety factor of three and a footing size 30 feet by 60 feet, as a rough approximation of the heavier loaded foundation slabs to be constructed. It should be mentioned here that it is not generally economical to spread the heavier loads sufficiently to reduce the soil pressure to 2600 pounds per square foot. However, even with this soil pressure the expected total settlement of the 30 by 60 foot slab was calculated to be from 4 to 6 inches. While plants have been constructed to accommodate such settlement at locations where compressible soil extends to great depths, it was possible to avoid this at the Delta site by carrying the loads down to the firm sand layer by means of piles.

Creosoted southern pine piles, Class B, to carry a working load of 25 tons, were selected as the most economical type which would be satisfactory in the circumstances. These were placed under turbine-generators, boilers, main auxiliary equipment foundation mats, circulating water pumps, elevated water tank, power transformers and control house columns. Piles were also placed under the intake structure at the Sunflower River as protection against possible scour, the floor of this structure resting in sand and very little below the level of the river bed.

Other structures at the plant were placed on spread footings on the soil, the loading being kept low and the possible harmful effects of settlement avoided by other means. In the case of the service building, which covers a fairly large area, an 18 inch thick foundation mat was placed in order to avoid differential settlements which might cause cracks in the building walls. Fuel oil tanks were placed directly on the ground on a six inch sand cushion, with a shallow, reinforced concrete collar under the perimeter of each tank to prevent high local concentration of shear in the soil at the edge of the tank.

Lengths of piles used varied from 35 to 50 feet. Some difficulty was experienced in pile driving because of the erratic nature of the clay strata encountered. Occasional lenses of hard clay caused breakage of the piles. This breakage was difficult to distinguish from simple failure of the pile to reach the specified driving resistance when it was too short. A number of piles were pulled for examination after failing to reach the required resistance when the butt had reached cut-off elevation and sometimes one pile had broken and another had not when only a few feet apart. Additional piles were driven to replace all those failing to meet specifications. Exploration by water jet was made at a number of points to make sure the piles were seated in the sand, because the elevation of this stratum varied somewhat over the plant area. The piles were driven with a Vulcan No. 1 single acting steam hammer to a capacity of 35 tons, as computed by the Engineering News formula. Driving to more than working capacity is commonly practiced as an additional safety measure. It should be mentioned that the pile breakage could not be tied to this relatively hard driving, but usually occurred below a resistance corresponding to 20 tons capacity. There was no other experience record

with which to compare notes because of the absence of other pile-supported structures in the vicinity.

Reinforced concrete foundations at Delta Station are of conventional design. Each turbine-generator pedestal is supported on a mat three and one half feet thick, which also extends under the condensers. Each boiler is supported on a mat four feet thick. The mats under equipment bays are two and one half feet thick. This mat construction was used for several reasons. One was simply to provide sufficient area for the number of piles required. Another was that the stiffness of the mat prevents large differential settlements in short distances. Still another reason was that in a compact arrangement, separate equipment and column foundations tends to interfere with each other while a common mat permits spacing of equipment close to columns and other equipment.

The results of stress analyses of the reinforced concrete mats are, of course, approximations because of the complexity of the two-way slab action. Briefly, the mat is commonly assumed as a rigid body, causing straight line variation of soil pressure or pile loading. Moments and shears at any section are then computed using the loads above the mat and these computed loads from below. This method results in computed moments which are probably larger than actual. The amount of reinforcing steel is on the safe side but not excessively so. When piles are used, the moments are reduced by grouping the piles under the loads as much as possible.

The turbine-generator pedestals are of a massive reinforced concrete construction. One of the chief considerations in design of the pedestal is to avoid natural periods of vibration which are synchronous with the rotation of the machine. Since the period of vibration is a function of the stiffness of the pedestal members, this is controlled by limiting the allowable deflection of the members under their working loads. The result is more massive than is required merely to support the loads. All parts of the pedestal are reinforced with a minimum of about one per cent of steel.

Condensing Water System

The Big Sunflower River, where it passes Delta Station has an estimated maximum flow of around 7000 second feet, a minimum flow of 130 second feet and a flow above 300 second feet for fifty per cent of the year. Early studies indicated that direct use of the river water for condensing with recirculation upstream, would not be economical because of the cost, and there would also have been difficulty in obtaining water rights. The problem was thus reduced to comparison of cooling systems at the plant, with river water for make-up. The idea of a cooling pond was suggested by the flat terrain and the tight clay character of the surface soil as indicated by water which stands on the surface for long periods. An above-ground reservoir was suggested, with dykes to be made of the surface clay material. Weather records show that annual natural evaporation and annual rainfall are above equal, each amounting to about four feet in a moderately dry year. A study was made for a pond of one square mile area, using the Throne formula[2] to determine the forced evaporation and the expected condenser inlet water temperatures. From study of data on other lakes, a depth of ten feet of water was chosen so as to provide adequate stratification of thermal layers and to insure some storage against possibility of insufficient make-up being available. The pond

2. Presented in Paper before Regional Meeting of ASME at Dallas, Texas, March 1950.

was designed so that under average operating conditions, with two 100 mw units, the average summer inlet water temperature will not exceed 85 F. A comparison showed that such a pond would be more economical than a conventional cooling tower on the basis of the two 100 mw units only. Operating experience will dictate the economic limit of the pond's cooling capacity.

The water area of the pond is 580 acres. It is enclosed on four sides by a rolled filled dyke of native surface clay material 15 feet high, and 15 feet wide on top. The side slope on the water face is 3 to 1, and on the land face 2-1/2 to 1. An intake structure and a discharge structure are set 180 feet apart in the west leg of the dyke, adjacent to the plant, and a barrier, partly creosoted timber and partly earth dyke separates these structures and extends 4000 feet into the pond. The pumps at the pond intake force the water through the condensers and back to the discharge structure where the barrier causes the warm water to traverse the width of the pond and back in order to return to the intake structure. The quantity of cooling water circulated for the two initial units will be 140,000 gpm or 310 second feet. Make-up water is pumped from an intake at the Big Sunflower River. The pumps there are sized to make up the loss caused by forced and natural evaporation and by seepage from the pond. Make-up is estimated to be a maximum of 11 second feet for the first two units.

At the pond location the ground was thoroughly explored over the whole area. Tests were made on remoulded samples of the clay to determine the stability of the material in the dyke, and the stability of the ground under the dyke load. Permeability tests were made to determine the probable rate of seepage. These tests indicated that the coefficient of permeability of the natural clay and silty clay subsoils is generally 1×10^{-8} centimeters per second, or less, which means that the seepage through the subsoil down to the sand which underlies the clay will be negligible so far as pumping of make-up water is concerned. As a matter of fact, a small amount of seepage will be advantageous in that it will postpone the time when the water in the pond will have reached the maximum tolerable concentration of solids. For purposes of design a seepage of 2 second feet was estimated and no blowdown was provided initially at the pond to reduce the concentration.

In addition to the test holes to obtain representative samples of ground material, a checkerboard of auger holes about ten feet deep and 300 feet apart was made to insure that a continuous layer of impervious material existed under the pond floor. Generally, this layer is quite thick, but it diminishes to about five feet thickness in the northeast corner of the pond. Other tests included compaction tests, of the surface material to be used for the dyke in order to determine optimum moisture content for compaction.

The material used in the dyke was taken from the first two or three feet of depth of soil. The rolled fill was made by the accepted methods of today and construction was carried on during the fall and winter of 1952, and approximately 900,000 cubic yards of fill were placed in main dyke and baffle dyke. Frequent delays were occasioned by rainstorms, which made the material too wet to handle, but the fill was rolled to specifications. The top of the dyke is 5 feet above normal high water level and a berm ten feet wide was placed five feet below water level on which to rest riprap or other type of facing as protection against wave action. It was felt, however, that the compaction of the material, together with its natural cohesiveness might make this protective facing unnecessary. Filling of the pond was started soon after completion of construction since this would require a fairly long period using the make-up pumps. When the water reached shallow depths against the dyke,

it became evident that protective facing would be required. The compacted material swelled and became vulnerable even to ripples, which slowly undercut the face and deposited the material in a longer slope. Investigations were made to determine the most economical type of protection which would be adequate. Particular advantage was taken of the experience of the Corps of Engineers in their work along the banks of the Mississippi River in the vicinity. From the results of their experience over several years with bituminous facings, it appeared that a four inch blanket of hot sand-asphalt mix would be adequate. This was constructed by a paving contractor. Although the dyke has five feet freeboard, this facing extends only to three feet vertically above normal high water, this distance representing the estimated maximum height to which waves will reach. During the period of investigation of suitable facings, the filling of the pond was suspended just below the level of the berm in the dyke, and in order to avoid undue delay in the filling, a portion of the slope just above the berm was faced with six inches of coarse gravel, which was given a penetration coat of asphalt. Asphalt of 85-100 penetration was used for both types of work. The dyke face below the berm eroded somewhat during this period but was given no treatment, since it will be protected always by sufficient depth of water. Downstream faces of the dyke are seeded with grass.

Filling of the pond has been continued through the summer and fall of 1953. At this writing the pond is about three quarters full.

Make-up water is pumped one half mile from a reinforced concrete intake structure at the Big Sunflower River through an 18 inch steel pipe to an outlet box in the eastern side of the cooling pond. Low water level in the river is at Elevation 105, approximately 43 feet below normal high water level in the pond. The bed of the river is at Elevation 97 and the top of river bank is at Elevation 140, at the general elevation of the country in this vicinity. High water in the river may occur at any time. The intake operating deck was placed at the level of the top of river bank to avoid risk of inundation, since the maximum high water level is not known accurately. The initial installation of pumps consists of two vertical units of 3250 gpm each with provision for a future third pump, and these are protected by a trash rack and traveling screen. An access road reaches the intake structure at a point down the bank 12 feet below structure deck, with a steel stairway to the deck from roadway level. This is above ordinary high water and it was not considered justified to go to the expense of a bridge from the top of the river bank.

Intake and outlet at the pond are reinforced structures which form a part of the dyke and have their decks at the level of the roadway on top of the dyke. The outlet structure is a simple box, for four units capacity. The intake structure is built for the two initial units only, but space has been left for a second intake and steel sheet piling has been set in the wall to facilitate cofferdamming for future construction. The intake accommodates stop logs and traveling screens for each plant unit. Four horizontal centrifugal pumps, two for each unit, are mounted at ground grade outside the intake headwall. Each pump discharges through a separate 36 inch steel branch pipe to an 84 inch common steel manifold, which in turn connects to 84 inch reinforced concrete pressure pipe, which carries the water across the plant yard to the condensers. The discharge water is also carried back across the yard in 84 inch concrete pipe to the pond outlet structure. At the turbine-generator units, however, a change is made to cast-in-place twin concrete tunnels, one for inlet and one for discharge, which extends between the ends of the two units and have steel branch pipes from each tunnel to the four condensers served. The cast-in-place concrete tunnels serve as anchors against thrusts due to water pressure

at bends and in the branch pipes, and they also support deck columns and generator lead supports. In order to avoid stresses due to change of temperature in the branch pipe connections, expansion joints are placed in these branches at the condensers and Dresser couplings are placed midway in the branches, with the portion of the pipe next to the condenser anchored in concrete to take the thrust at that end. The thrust at the other end is taken by the tunnel.

The velocity of the water in the 84 inch condensing water pipes at Delta will be approximately 8 feet per second, the economic velocity for the pipe and the pumping. Very little water hammer is expected to occur in this pipe circuit under any operating conditions. In the long make-up line from the river to the cooling pond, a pump tripout could cause considerable pressure rise, but the steel pipe and valves are much stronger than necessary for ordinary working pressures.

Miscellaneous

A small but interesting feature at Delta Station is the sewage disposal system. A septic tank and leaching field were required, but the natural drainage conditions and the nature of the soil precluded the ordinary field layout. To overcome this difficulty the required layers of filter sand and gravel were built above ground and this fill was retained and protected by a ring dyke of native material with a cap of the same material to keep out rainwater. The concrete septic tank is situated at a central point in the plant yard, and the effluent from the tank is pumped a distance of about 1800 feet to the open tile system in the leaching beds. The system is designed for 80 persons, and the leaching field required 1800 cubic yards of sand and gravel and about the same quantity of clay material for dyke and cap.

Active design of Delta Station was started in the early fall of 1951 and construction was started on November 19, 1951. In spite of delays in shipment of plant equipment, trial operation of Unit No. 1 was made on October 31, 1953 and Unit No. 2 on December 5, 1953. The estimated cost of this 200 mw development is $21,575,000.

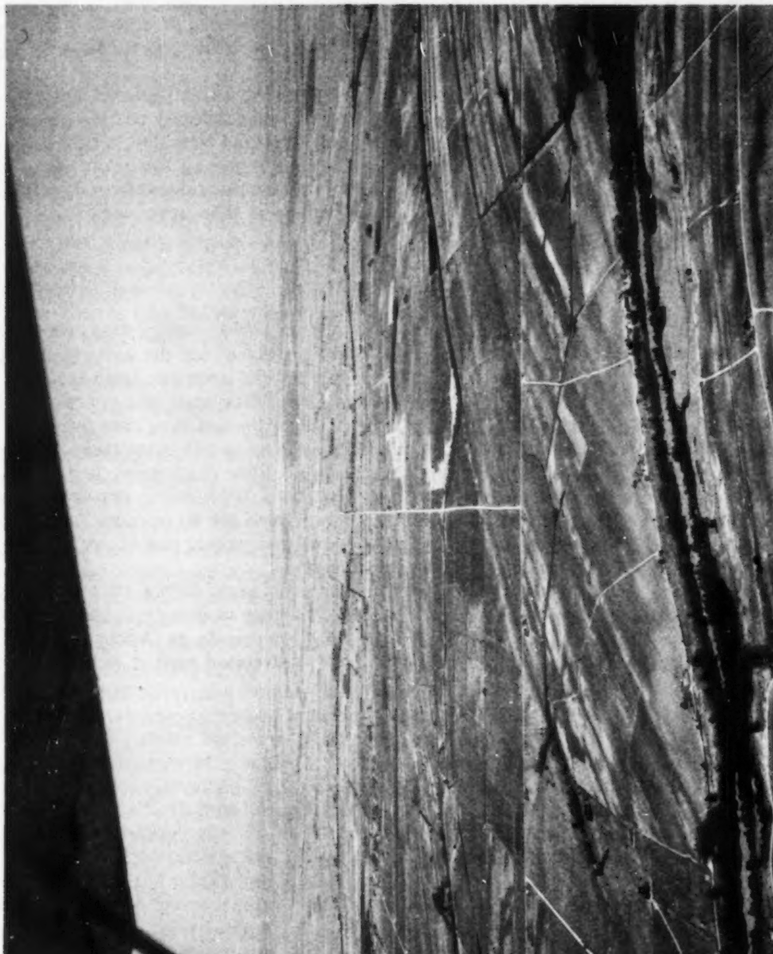
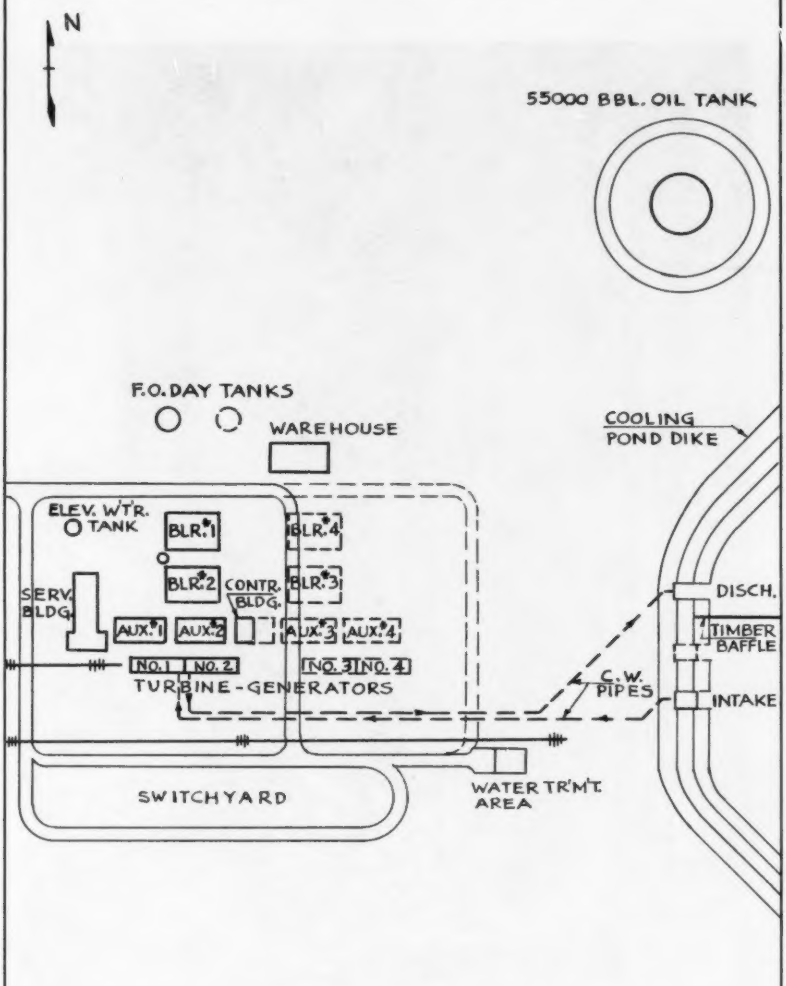


Fig. 1



PLOT PLAN DELTA STATION

Fig. 2

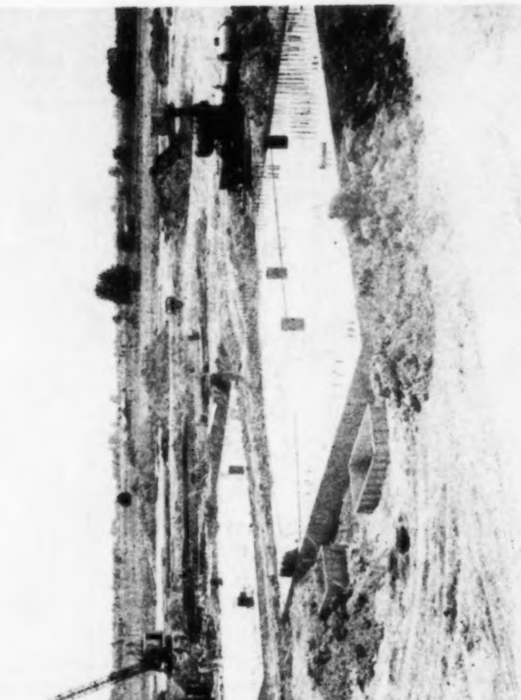


Fig. 3

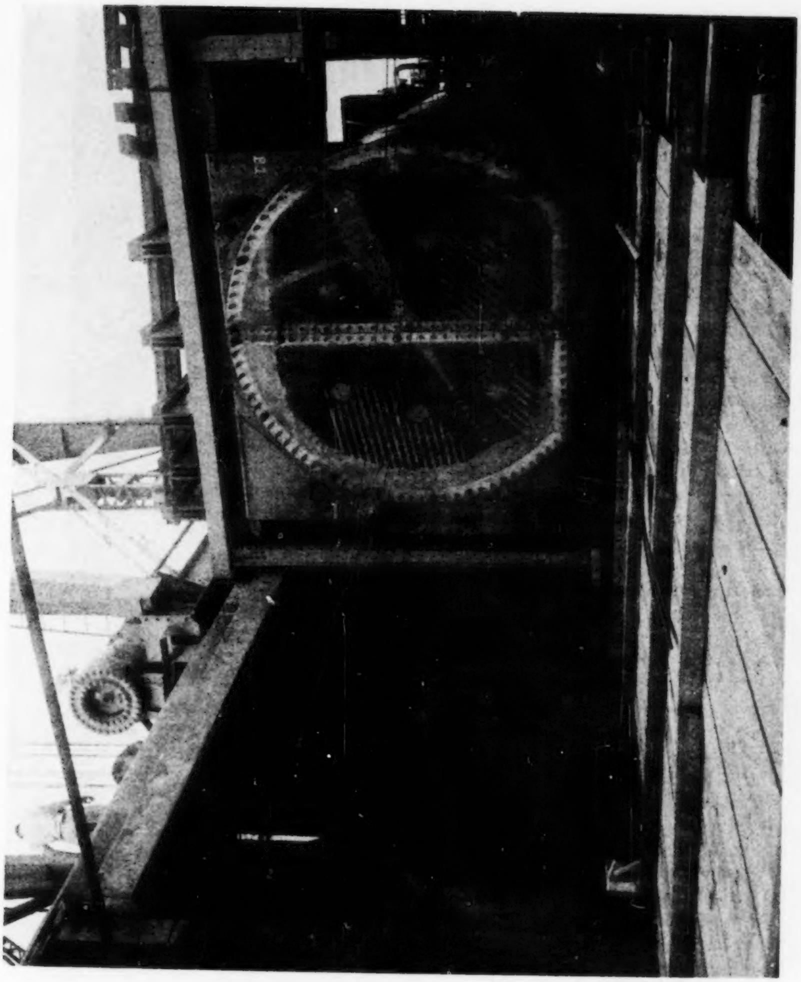


Fig. 4

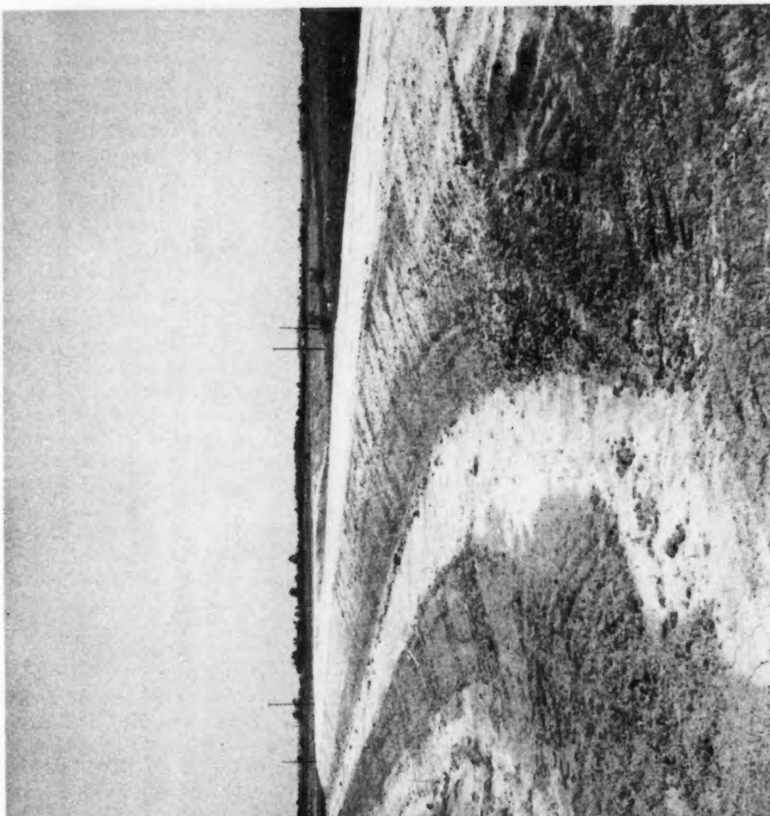


Fig. 5

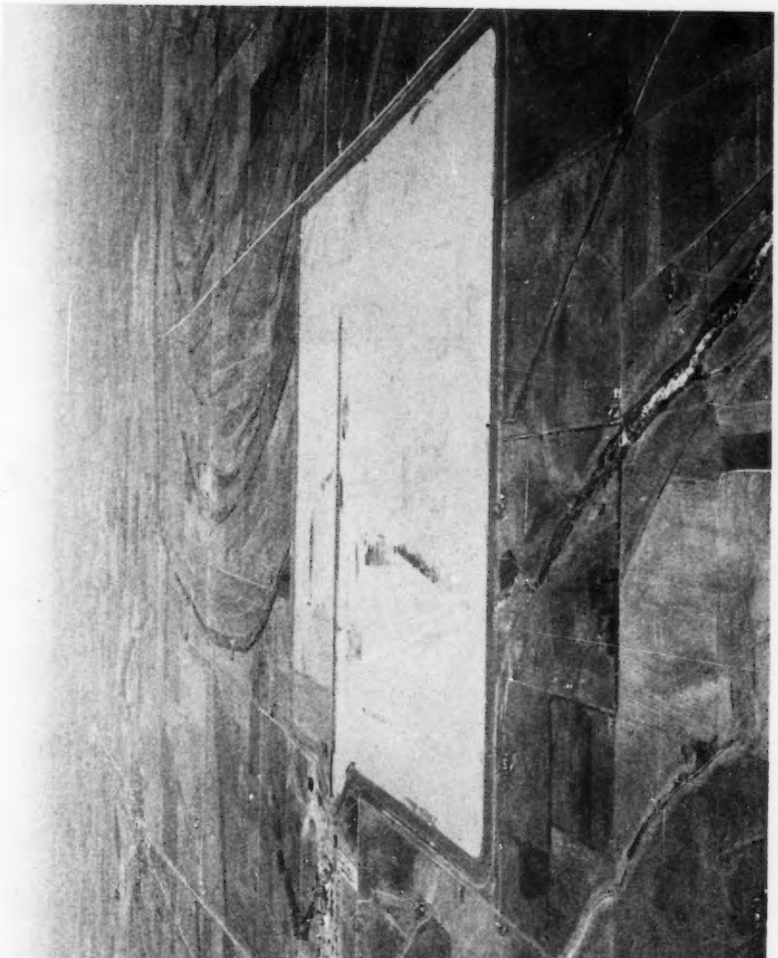


Fig. 6

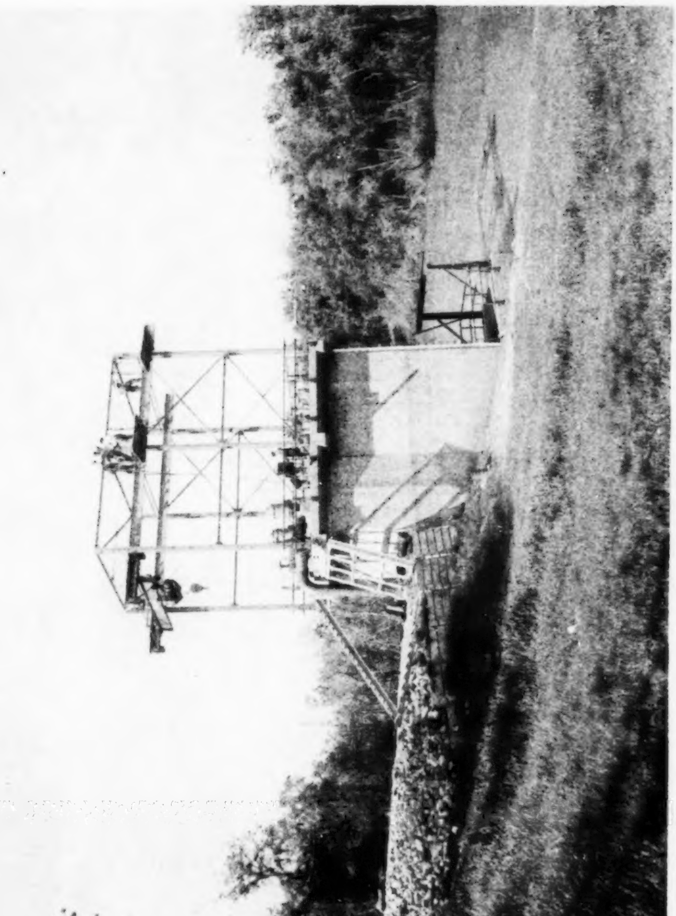


Fig. 7

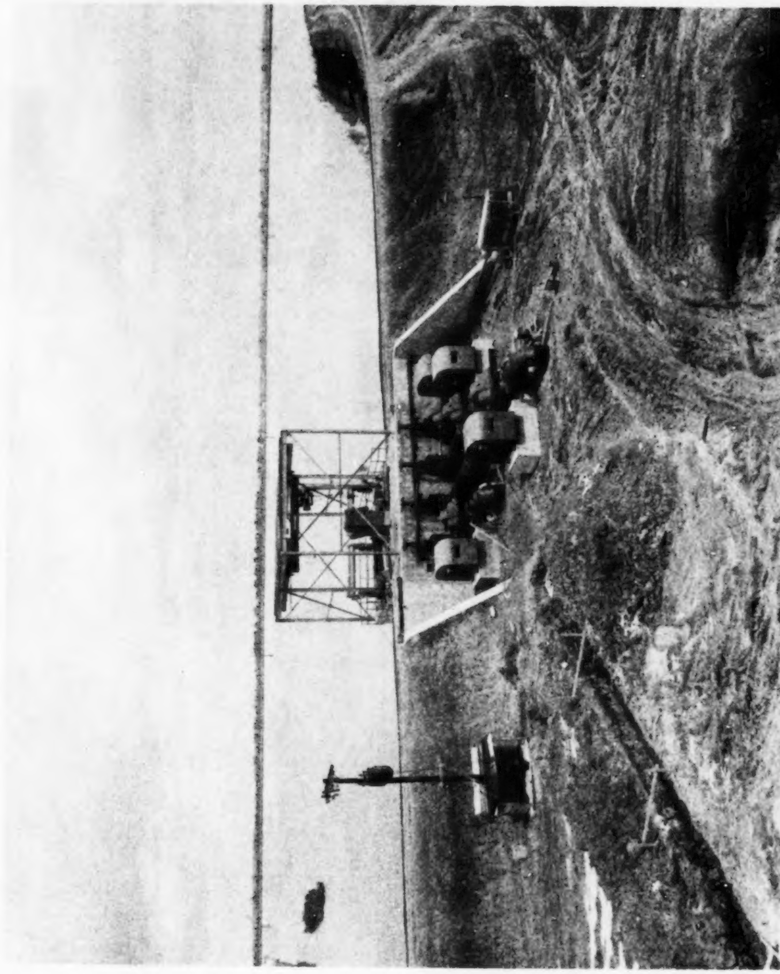


Fig. 8

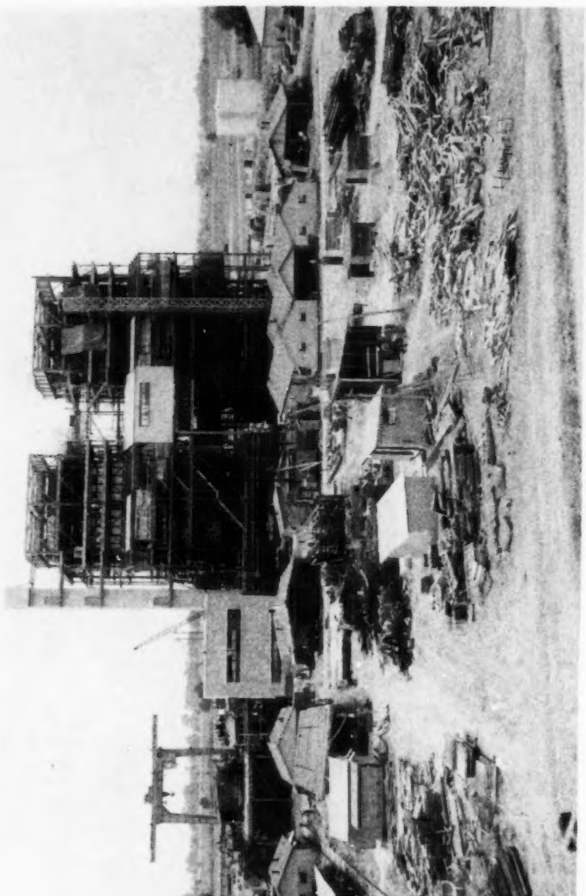


Fig. 9

Fig. 10